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(54) Multilayer recording

(57) A transparent substrate plate (13) is provided on one side with at least two radiation-reflecting optical structures (15–17, 25) each having a relief-like information track (15, 25) which is read by reflection and on the basis of occurring phase differences. At least one optical structure (15–17) is covered with a reflection layer (18) which partially transmits the incident reading radiation to allow reading of the other optical structure (25) which is covered with a reflection layer (26). The coefficients of reflection are preferably so matched that upon reading the same amount of light returns from each optical structure. A suitable partial reflection layer is a dielectric layer which shows no light absorption. A disc reproducer may reproduce information substantially continuously by reading one information structure in a radially outwards direction and an adjacent information structure in a radially inwards direction.

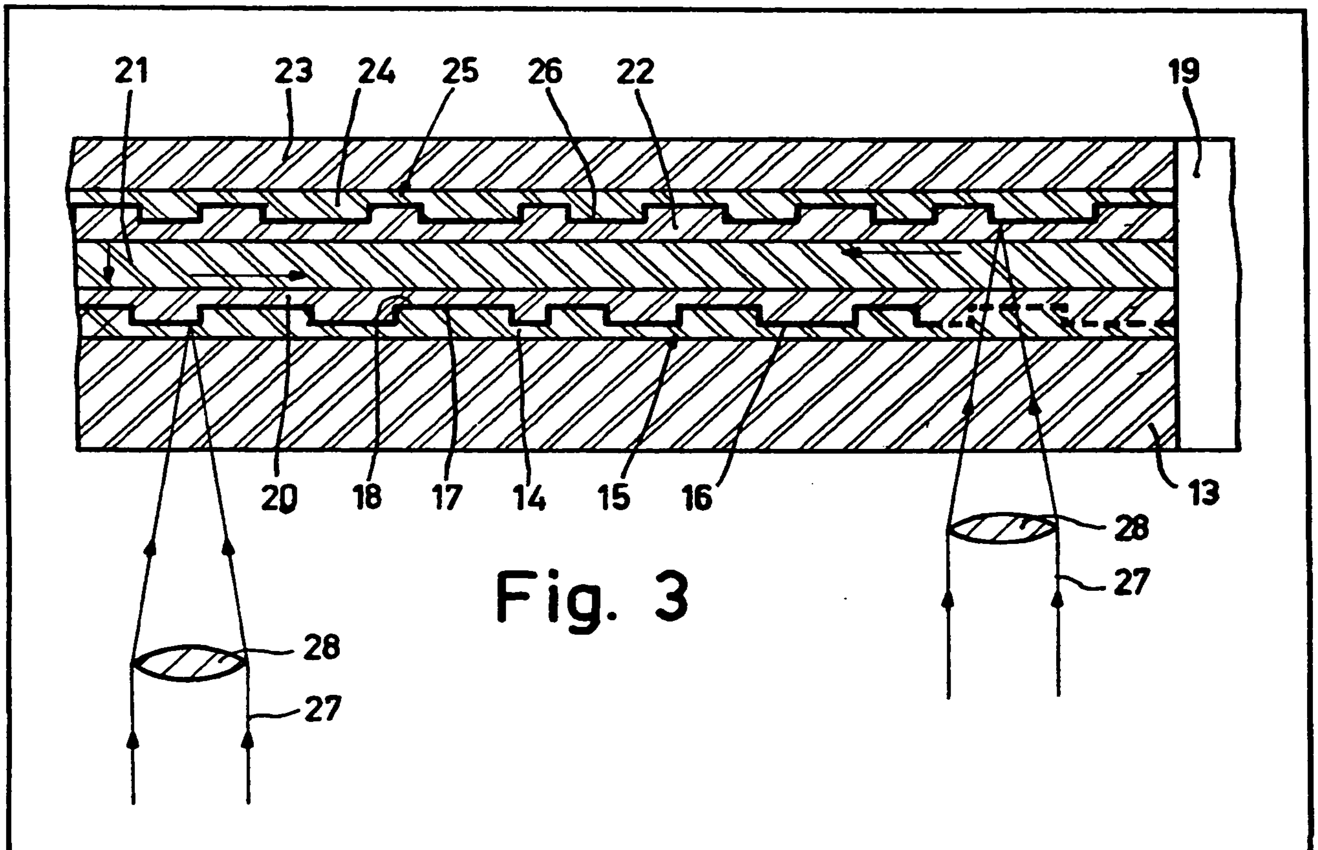

Fig. 3

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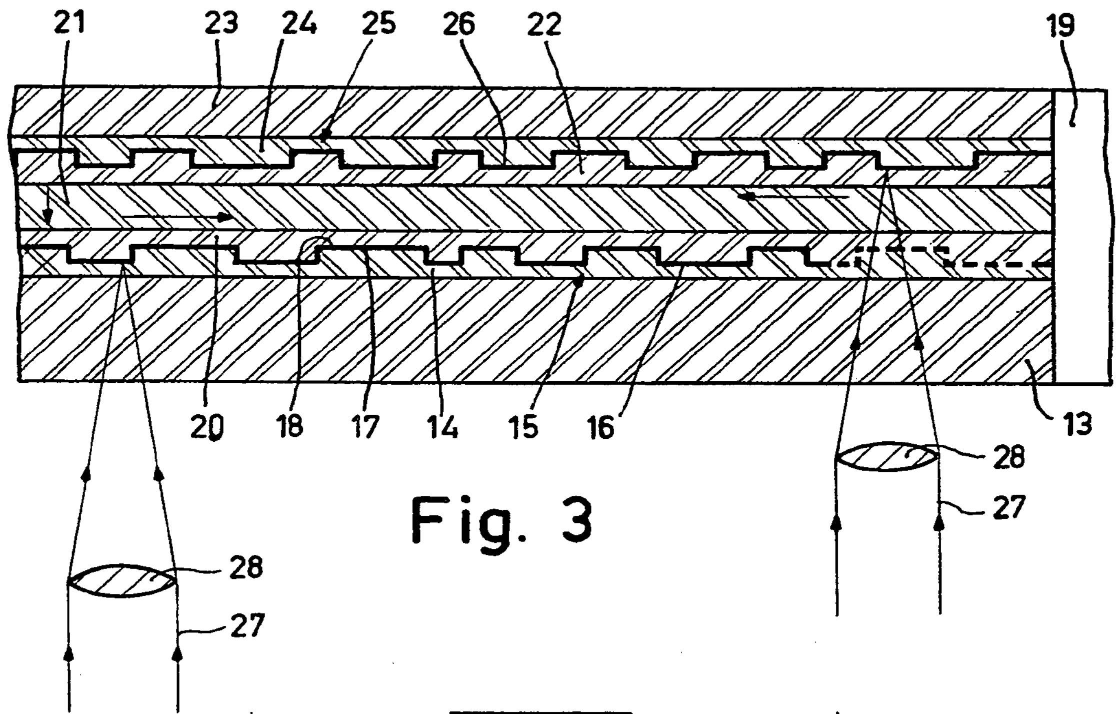
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Fig. 3

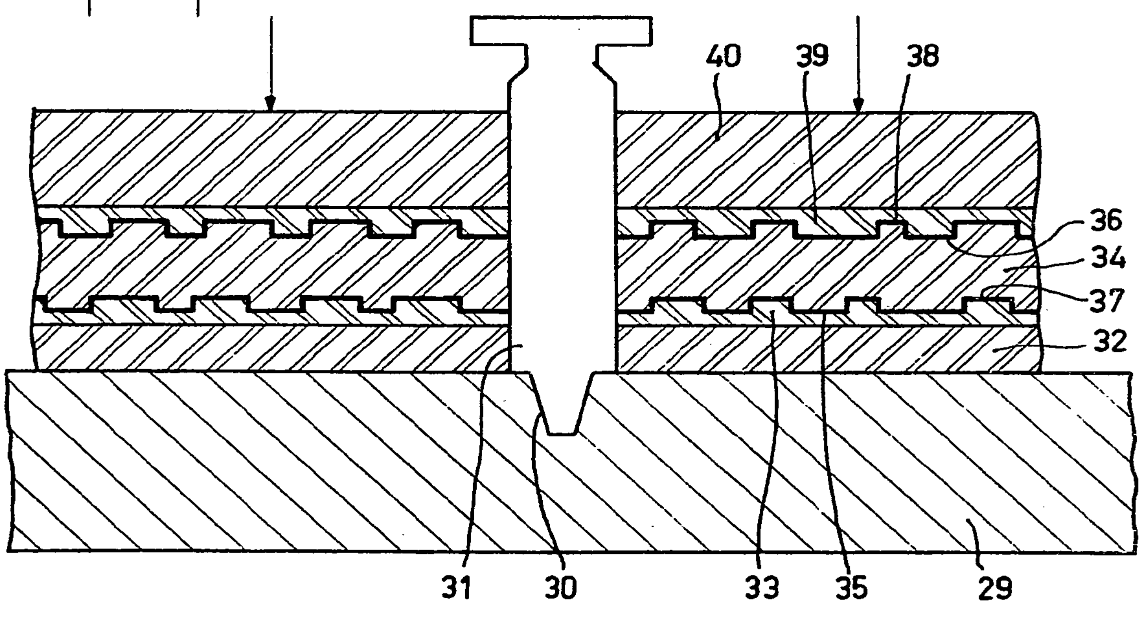
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Fig. 4

SPECIFICATION

Multilayer information disc

The invention relates to a multilayer information disc which is read optically in reflection and comprises two or several parallel radiation-reflecting optical structures which are separated from each other by one or several transparent spacing layers, each optical structure comprising an information track which has a relief structure of information bits situated alternately at a higher and lower level and being covered by a radiation-reflective layer.

An information disc of this type is disclosed in published Netherlands Patent Application 72 11 999 in the name of Applicants.

As is shown in Fig. 4 of the said patent application the known information disc comprises two parallel radiation-reflecting optical structures comprising an information track with relief structure which is covered by an optimally reflecting layer, for example a metal layer.

The optical structures are connected together with the interposition of a layer of synthetic resin, for example, a layer or foil of adhesive, and each comprise a transparent carrier on the side remote from the adhesive layer or foil. The disc is read in reflection from two sides *via* the carrier.

The manufacture of the known two-layer information disc is based on the combination, or more specifically the adhering, of two single discs which can each individually be readily played back.

The known information disc comprises a comparatively large quantity of synthetic resin. The composing single discs as a matter of fact both comprise a carrier which, for a good handlability, has a fairly large rigidity and hence thickness.

The invention provides a multilayer information disc which has a good information playback quality, can be manufactured in a simple and direct manner and requires comparatively little material.

In a special embodiment the invention further provides a multilayer information disc which wholly can be read from one side in reflection and has a long playing time. This presents the possibility of continuously reading in reflection a large amount of stored information, for example video information. During the reading operation the disc need not be turned over. A playing time of approximately two hours can be achieved so that a T.V. program of such a long duration stored in the disc can be played back without interruption.

The invention relates to a multilayer information disc of the kind mentioned in the preamble which is characterized in that the disc comprises at least one optical structure which is covered by a reflection layer which is partially radiation-transmitting and which upon reading the other optical structure or structures is traversed by the reading light beam focused on the other structure or structures.

In a simple and very cheap embodiment the information disc comprises two radiation-reflecting optical structures which are separated by a transparent spacing layer and which are both provided with a partially transmitting reflection layer.

The two optical structures preferably have the same coefficients of reflection which may vary from 20 to 50% reflection.

The above-described two-layer information disc according to the invention is read optically by means of a highly energetic light beam, for example a laser light beam, which is focused, by means of an objective, on one of the two optical structures, namely that one which is farthest remote from the objective. This means that during reading the laser light passes through the most adjacent first optical structure which is out of focus, whereby a part of the initial laser light is reflected by the partially transmitting reflection layer of said first optical structure. The amount of transmitted light traverses the transparent spacing layer and is then reflected partly by the second optical structure to be read. The second optical structure is in focus. The reflected light is modulated upon reflection in accordance with the stored information. The modulated laser light traverses the transparent spacing layer in the reverse direction and again passes through the first optical structure. A part of the light is reflected, the transmitted modulated laser light is received and processed in known manner in the optical playback apparatus.

During reading the first optical structure, the laser light which is focused on the first structure is incident *via* the second optical structure and the spacing layer. This means that in the above-described simple embodiment of an information disc according to the invention the disc has to be turned over to read the information present in both structures.

Since the laser light during reading an optical structure always traverses the spacing layer, the dust particles and scratches, if any, present on the surface of the disc and situated beyond the depth of focus of the objective will not have a detrimental influence on the quality of the read and displayed information. The spacing layer should have a minimum thickness of approximately 100–200 μm.

The amount of modulated laser light which is received during reading an optical structure

The reading light beam, for example, a high-energy laser light beam, is incident *via* the substrate plate and focused to the desired optical structure to be read in reflection by means of an objective. The sequence of reading of the various optical structures is of no principle importance and may be chosen arbitrarily. This will be referred to hereinafter. When reading an optical structure situated farther from the substrate plate, the optical structure (structures) situated more inwardly, that is nearer to the substrate plate, will be traversed by the reading light beam. With the exception of the outermost optical structure, the remaining structures are covered with a partially transmitting reflection layer. The outermost optical structure may also be covered with a partially transmitting reflection layer but preferably has a reflection layer having the highest possible coefficient of a reflection, for example, a metal layer having a reflection of 90–100%.

The amount of light resulting from an optical structure during reading depends on the reflection of the optical structure or structures which is or are situated between the substrate plate and the focused optical structure.

In a favourable embodiment of the information disc the radiation-reflecting optical structures have mutually different coefficients of reflection, the coefficient of reflection being larger as the optical structure is situated at a larger distance from the substrate plate, the coefficients of reflection being matched to each other in such manner that upon reading the disc by means of a light beam incident *via* the substrate plate the amount of light resulting from each optical structure is equal or substantially equal.

The equal amount of light, in which a difference of 10% is still tolerable, has the practical advantage that the playback apparatus need not comprise light compensating means.

It is of importance for the amount of light returning in reflection from the optical structures to be as large as possible. The ratio of resulting light and incident light depends on the number of optical structures—the ratio becoming smaller with a larger number of structures—and on the coefficient of reflection of the various optical structures.

Very good results are obtained with a two-layer information disc which is characterized in that the substrate plate is provided on one side with two radiation-reflecting optical structures separated by a transparent spacing layer, the first optical structure situated near the substrate plate having a coefficient of reflection which varies from 25 to 40% reflection and the second optical structure situated farther away having a coefficient of reflection which varies from 45 to 100% reflection.

Good results are also obtained with a three-layer information disc which in general has a lower light output but on the other hand a longer playing time. A suitable three-layer information disc according to the invention is characterized in that the substrate plate is provided on one side with three radiation-reflecting optical structures which are separated from each other by two transparent spacing layers, the first optical structure situated nearest the substrate plate having a coefficient of reflection which varies from 20 to 25% reflection, the second optical structure situated farther away having a coefficient of reflection which varies from 30 to 40% reflection, and the third optical structure situated farthest from the substrate plate having a coefficient of reflection which may vary from 60 to 100% reflection.

In tables 2 and 3 the amount of reflected light resulting from each optical structure is recorded as a function of the coefficient of reflection of the optical structure which is expressed in percentage of reflection. The sequence of the optical structures is taken from the substrate plate so that the indicated first structure is situated nearest to the substrate plate. No absorption of light takes place. Table 2 relates to a two-layer disc; table 3 relates to a three-layer disc.

Table 2

	coefficient of reflection expressed in percentage of reflection		reflected light expressed in percentage of incident light	
Information disc Nr.	first structure	second structure	first structure	second structure
1	15	20	15	15
2	20	31	20	20
3	25	45	25	25
4	30	61	30	30
5	38	100	38	38
6	40	100	40	36

When several optical structures are present between the outermost optical structure and the substrate plate, all intermediate structures in the central part of the disc are not provided with the partially transmitting reflection layer.

It is also possible to read the optical structures in the same direction, for example, from the centre towards the edge. For this purpose, for example, the laser light beam is focused on the first structure adjoining the substrate plate which is read from the centre towards the edge. The information track of the first structure comprises on the outer side a code signal so that the laser light beam is focused on the overlying structure. The information track of the second structure comprises on the outer side a "lead-out" signal, that is a code indicating the end of the disc. As a result of the "lead-out" code, the laser light beam travels towards the centre in approximately 25 sec. without reading taking place. The inner side of the second optical structure comprises a "lead-in" signal so that the laser light scans the second optical structure from the centre towards the edge.

Due to the said delay of 25 sec. the above-described alternating reading process is to be preferred.

The transparent substrate plate of the information disc may be manufactured from glass but preferably consists of a foil or plate of a transparent synthetic resin, for example, PVC, polymethylmethacrylate, polycarbonate or a copolymer of vinyl chloride and vinyl acetate.

According to a favourable specific embodiment the information disc comprises the above-mentioned plate of transparent synthetic resin which is provided on one side with a radiation-cured first resin layer comprising the first information track, a first partially transmitting reflection layer on the first resin layer, a first spacing layer of transparent synthetic resin on the first reflection layer, a second radiation-cured resin layer having a second information track provided on the first spacing layer, a second reflection layer on the second resin layer and, if desired, a second or subsequent spacing layer comprising a third or subsequent resin layer with therein the third or subsequent information track which is covered with the third or subsequent reflection layer, the last radiation-reflecting layer being covered with a protective layer.

The radiation-cured resin layer preferably is a U.V. light-cured photosensitive lacquer on the basis of acrylic acid esters.

Suitable lacquers which after curing adhere to synthetic resin and do not or only slightly adhere to metal are aprotic mixtures of monomers and/or oligomers on the basis of mono-, di-, tri- or tetra-esters of acrylic acid.

An excellently suitable lacquer comprises 50–80% by weight of a monoacrylate, 5–40% by weight of a di-, tri- or tetraacrylate, as well as 1–3% by weight of an initiator. As an initiator a benzoin derivative may be used, for example, benzoin-isobutyl ether.

Examples of esters of acrylic acid to be used in the lacquer are alkyl acrylates, for example ethyl acrylate and 2-ethyl hexyl acrylate, alkoxyalkyl acrylates, for example ethoxy ethyl acrylate, phenoxyalkyl acrylate, phenyl acrylate, diacrylates, for example alkanediol diacrylates, for example 1,3-hexanediol diacrylate, alkeneglycol diacrylates, for example tripropyleneglycol diacrylate, triacrylates, for example trimethylolpropane triacrylate and oligomeric acrylic acid ester, for example polyester acrylate and epoxy acrylate.

Readily useful specific lacquer compositions are described in the non-prepublished Netherlands Patent Application 76 11 395 in the name of Applicants which is incorporated by reference.

It is of importance that during reading the information disc according to the invention the reading light beam should be used as optimally as possible and that no light is lost.

In a favourable embodiment the information disc comprises a partially transmitting reflection layer which does not absorb the reading light beam or absorbs it only to a slight extent.

Very suitable partially transmitting reflection layers which show no noteworthy light absorption are layers which comprise a dielectric.

This applies in particular to layers comprising as a dielectric zinc selenide, bismuth oxide, cadmium sulphide, cadmium telluride or combinations thereof. In particular zinc selenide is very readily useful. It may be noted that partially transmitting thin metal layers may also be used, for example, layers of Ag, Ni or Al in a thickness of approximately 100 to 200 Å. However, a certain extent of light absorption takes place, for example a light absorption of approximately 10 to 20% occurring with a partially transmitting silver layer. The value of reflection and absorption of a metal layer depends on the thickness. Reference may be had to Journ. Opt. Soc. Am., Vol. 44, No. 6, pp. 429–437.

The reflection of a dielectric layer depends on the type of dielectric and the thickness. When a monolayer dielectric is used, for example, a layer of ZnSe, the value of reflection can be influenced only to a small extent by thickness variations. The maximum achievable reflection in this example is approximately 35% reflection.

When an assembly of several dielectric layers is used with alternately high and low indices of refraction, a partially transmitting reflection layer can be obtained having a coefficient of reflection which can be adjusted over a very large reflection range. For the composition and

mm thick foil of polymethylmethacrylate which is provided on both sides with a radiation-reflecting structure 2. The radiation-reflecting optical structure 2 comprises a cured resin layer 3 which engages the foil surface and in which an information track 4 is present. Resin layer and information track are provided by placing the foil 1 (see Fig. 6) on a nickel matrix 60 which is provided with an information track 59 and has a thin layer (about 30 μm) of a U.V. light-curable lacquer 61 and then exposing the lacquer layer *via* the foil in the direction denoted by the arrows and finally removing from the matrix the foil with connected thereto the cured resin layer in which the information track is copied. The same process is then applied to the other surface of the foil. The U.V. light-curable lacquer comprises 58% by weight of 2-ethylhexyl acrylate, 20% by weight of 1,4-butanediol diacrylate, 20% by weight of 1,1,1-trimethylolpropane acrylate and 2% by weight of benzionisobutyl ether.

A partially transmitting reflection layer 5 of zinc selenide in a thickness of approximately 80 nm is provided on the resin layer 3 (Fig. 1). The reflection layer has a reflection of 33% and shows further no light absorption. The reflection layer is covered with a protective lacquer not shown. The optical structures 2 are read by laser light 6 which is focused on the farthest remote optical structure by means of an objective 7. The amount of modulated laser light resulting after reflection against the focused structure is approximately 15% of the incident amount of light (see also Table 1 of the preamble).

Fig. 2 shows another embodiment of a two-layer information disc which is read in the same manner as in Fig. 1. The disc shown in Fig. 2 comprises a transparent PVC foil 8 in which two information tracks 9 are provided by means of a pressing process, printing process or injection moulding process. The information tracks have a crenellated profile and comprise blocks 10 at a higher level and pits 11 at a lower level with variable longitudinal dimensions in the order of magnitude of from 1 to a few μm. Both surfaces of the foil 8 are provided with a thin layer 12 of zinc selenide which is partially transmitting and has a reflection of 33%. The reflection layer is covered with a protective lacquer not shown.

Reference numeral 13 in Fig. 3 denotes a transparent substrate plate in the form of a 1 mm thick PVC foil. Substrate plate 13 is provided on one side with a U.V. light-cured resin layer 14 in which the information track 15 is provided. The information track 15 which consists of pits 16 and blocks 17 is covered with a partially transmitting reflection layer 18 of zinc selenide having a reflection of 33%. The information track 15 in the central part of the information disc, that is adjoining the central hole 19, is not provided with the reflection layer 18 over a distance of approximately 1 mm. This is shown in the Figure by a broken line. *Via* an adhesive layer 20 the substrate plate 13 comprising information track 15 and reflection layer 18 is connected to spacing foil 21 in the form of a 0.15 mm thick transparent PVC foil which has a second adhesive layer 22 on the surface remote from the substrate plate 13. *Via* adhesive layer 22 the spacing foil is connected to a second transparent PVC foil 23 having a thickness of 0.15 mm which on its surface facing the adhesive layer 22 comprises a U.V. light-cured resin layer 24 in which a second information track 25 is provided which is covered with a silver layer 26 which adjoins the adhesive layer 22 and shows a reflection of 90%.

The multilayer disc is read in the direction denoted by arrows in Fig. 3 in which a laser light beam 27 is focused, by means of objective 28, on the farthest remote structure (25, 26) which is then read from the right to the left. The objective then drops, focuses the first structure (15–18) which is then read from the left to the right. The amount of light resulting both from the first and the second optical structure after reflection is 33% of the originally incident amount of light.

Reference numeral 29 in Fig. 4 denotes an assembly platform, for example, the rotating disc of a centrifuge. The platform has a central, mainly conical hole 30 in which one end of a centring pin 31 fits. A synthetic resin foil 32 having a thickness of 0.15 mm and provided with a central hole is situated on the platform 29. On its surface remote from the platform 29 the foil has an adhesive layer 33. A second transparent PVC foil 34 having a thickness of 0.15 mm is provided on layer 33 and also comprises a central hole. Foil 34 is provided on both sides with information tracks 35 and 36 provided in the foil surface by means of an injection moulding or printing process. Information track 35 is covered with a layer 37 of Ag engaging adhesive layer 33 and having a reflection of 90%. Track 36 is covered with a zinc selenide layer 38 showing a reflection of 33%. Present on track 36 is a second adhesive layer 39 and thereon a third transparent PVC foil 40 having a central hole and a thickness of 1 mm.

Fig. 5 is a cross-sectional view of a three-layer information disc, 41 denoting a 1 mm thick transparent plate of polymethylmethacrylate. Plate 41 has a light-cured resin layer 42 in which information track 43 is present. Resin layer 42 with information track 43 is covered for the greater part with a partially light-transmitting dielectric layer 44 having a reflection of 22%. The part of the resin layer situated near the central hole 45 is not covered with the dielectric layer over a width of at most 1 mm. This part is shown in broken lines in the Figure. The dielectric layer and hence also plate 41 is connected to a foil 47 of transparent PVC in a thickness of 0.15 mm *via* an adhesive layer 46 of light-cured resin. On the surface remote from the dielectric

transmitting reflection layer in the central part of the disc over a small radial distance.

11. A multilayer information disc as claimed in Claim 5, characterized in that the disc comprises a substrate plate of transparent synthetic resin which has on one side a radiation-cured first resin layer comprising the first information track, a first partially transmitting reflection layer on the first resin layer, a first spacing layer of transparent synthetic resin on the first reflection layer, a second radiation-cured resin layer having a second information track provided on the first spacing layer, a second reflection layer on the second resin layer and, if desired, a second or subsequent spacing layer having a third or subsequent resin layer with therein the third or subsequent information track which is covered with the third or subsequent reflection layer, the last radiation-reflective layer being covered with a protective lacquer.

12. A multilayer information disc as claimed in Claim 4 or 11, characterized in that the radiation-cured resin layer is a U.V. light-cured photo-sensitive lacquer on the basis of acrylic acid esters.

13. A multilayer information disc as claimed in Claim 12, characterized in that the photosensitive lacquer comprises 50–80% by weight of a monoacrylate, 5–40% by weight of a di-, tri- or tetracrylate, as well as 1–3% by weight of an initiator.

14. A multilayer information disc as claimed in any of the preceding Claims, characterized in that the partially transmitting reflection layer does not absorb the reading light beam or absorbs it only to a small extent.

15. A multilayer information disc as claimed in Claim 14, characterized in that the partially transmitting reflection layer comprises a dielectric.

16. A multilayer information disc as claimed in Claim 15, characterized in that the partially transmitting reflection layer comprises zinc selenide, bismuth oxide, cadmium sulphide or cadmium telluride or a combination thereof.

17. A multilayer information disc substantially as described with reference to any one of Figs. 1 to 5 inclusive.

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